LightMAT
Lightweight Materials
CONSORTIUM

Overcoming the Barriers to Lightweighting by Enabling Low-Cost and High-Performance Structural Automotive Aluminum Castings

AASHISH ROHATGI, Jens Darsell,
Tarang Mungole
aashish.rohatgi@pnnl.gov
Pacific Northwest National Laboratory (PNNL)

DAVID WEISS
david.weiss@eckindustries.com
Eck Industries

U.S. DEPARTMENT OF ENERGY | National Laboratory Impact Initiative

EMN Energy Materials Network

Project ID # mat158

June 13, 2019

Overview

Timeline

- Start: August 2018
- Finish: July 2020
- % complete (time): ~40%

Technology Gaps/Barriers

- High cost of “primary” Aluminum (Al) casting alloys
- Poor mechanical properties of “secondary” Al casting alloys

Budget

- Total project funding
  - DOE: $ 250K
  - Industrial cost share: $ 250K
- Funding Since Inception: $ 250K
- Future Funds Anticipated: $ 0

Partners

- Eck Industries

Relevance/Objective

- Aluminum content in light-duty vehicles
  - Current: 400 lbs. Al/vehicle; ~73% castings
  - Near future: ~500 lbs. Al/vehicle by 2025
- Challenges for greater Al usage
  - Higher cost of “primary” Al casting alloys
  - Poor mechanical properties of “secondary” Al castings
- Project scope
  - Heat-treatment techniques to lower processing cost of castings
  - Process molten-Al processing technique to enhance mechanical properties of “secondary” Al casting alloys
- LightMAT’s resources (at PNNL)
  - Help industry expedite technology development by enabling access to advanced testing and characterization techniques and scientific expertise, all under one roof

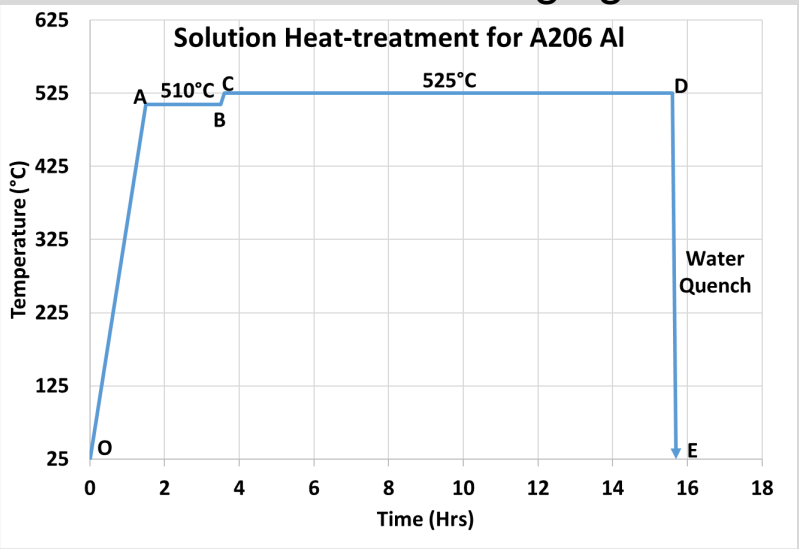
Knuckles

Brake Calipers

Approach

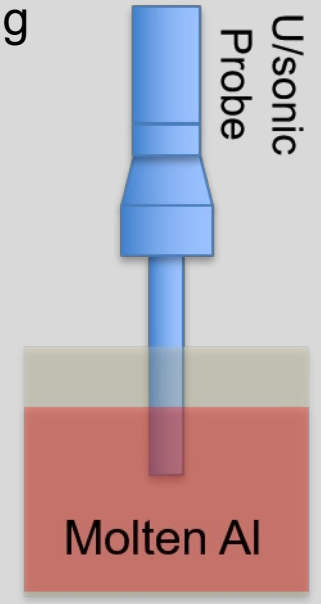
Heat-treatment Development

- A206 Al alloy: 4.6% copper (Cu) – 0.35% manganese (Mn) – 0.25% magnesium (Mg) – 0.22% titanium (Ti)
- PNNL proprietary
- Goal: Shorten solution/aging

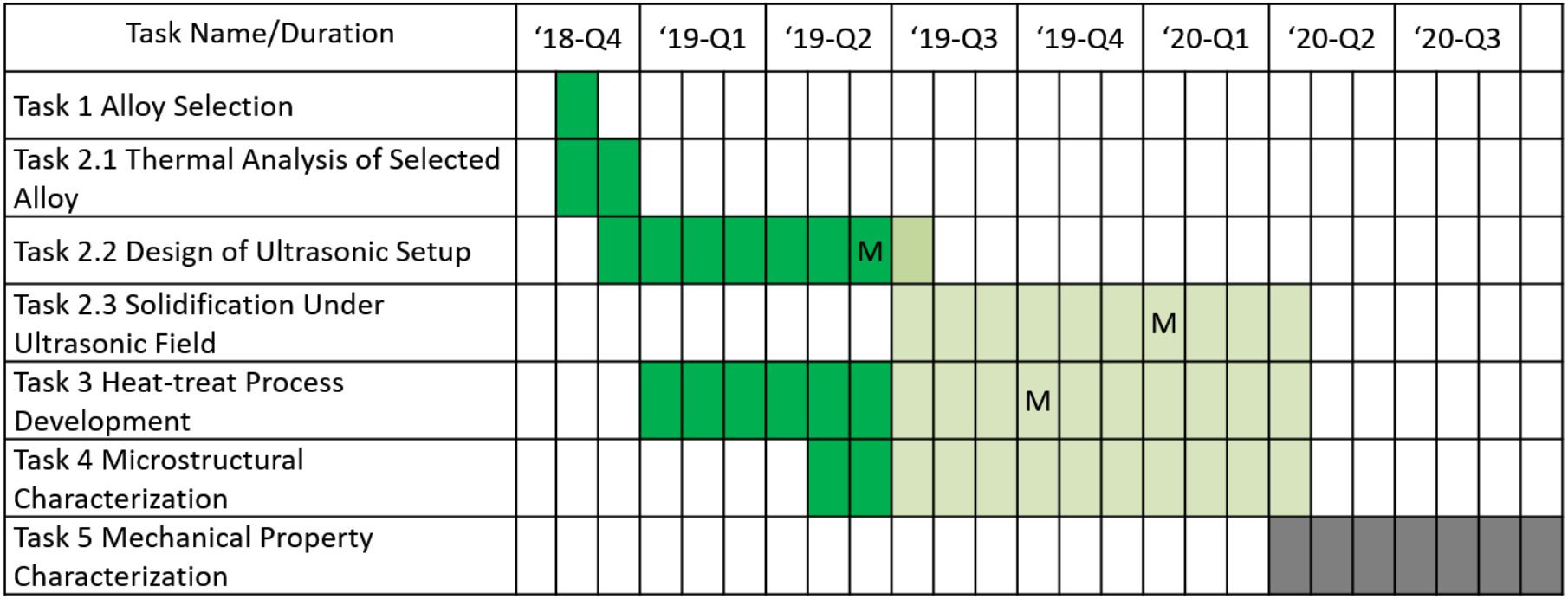


Molten Al Process Development

- A356 Al alloy: 6.5-7.5% (silicon) Si, 0.25-0.45% Mg, iron (Fe)…
  - 0.2% Fe (“primary alloy”)
  - 0.6% Fe (“secondary alloy”)
- Ultrasonic melt processing
- Goal: Refine the microstructure for finer intermetallics and lower dendrite arm spacing to improve ductility and more uniform properties throughout the casting

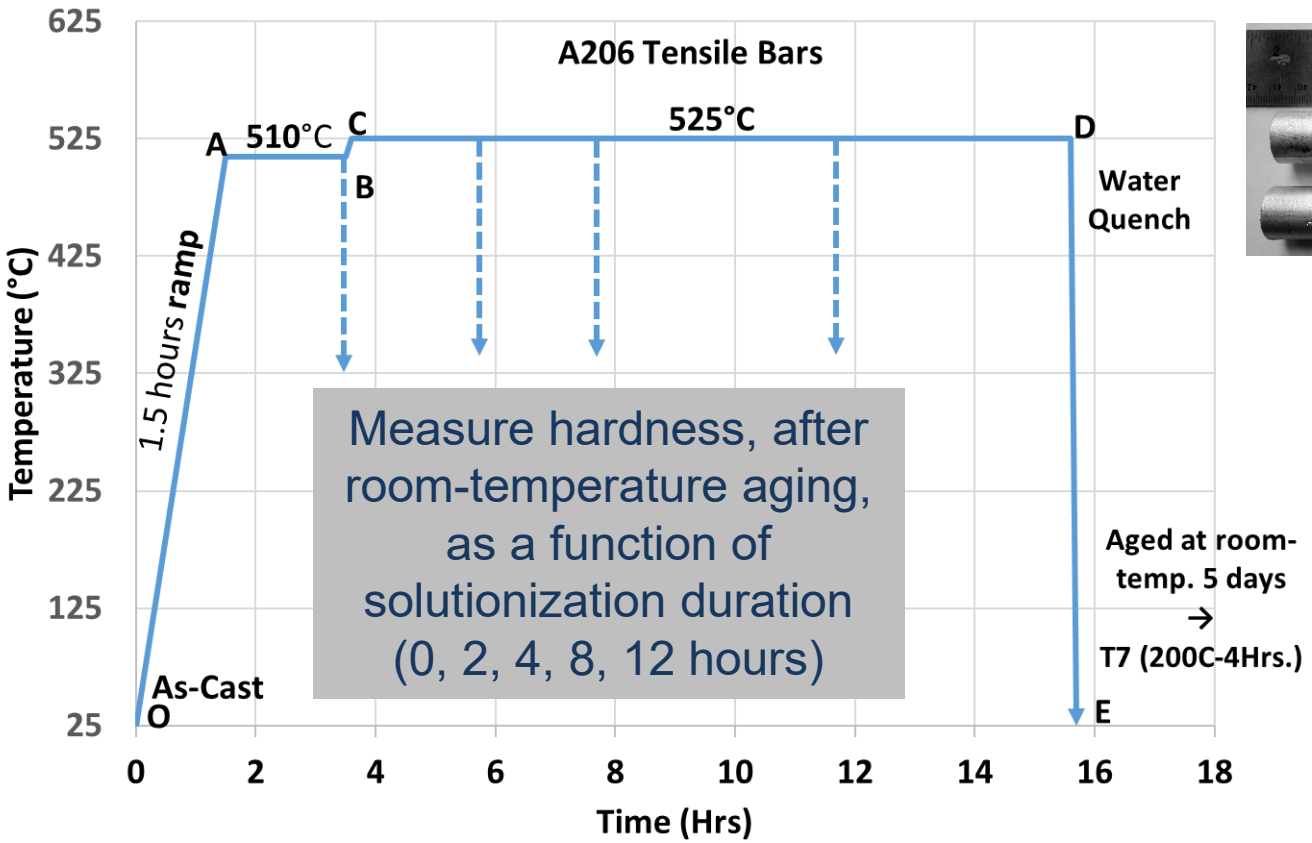


Task/Milestone Summary

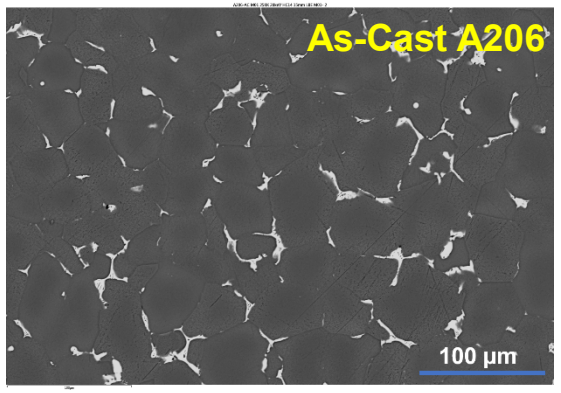


M1 (03/19): Setup an ultrasonic system for use in conjunction with molten alloys
M2 (07/19): Compare hardness and microstructure of A206 following baseline and the alternate heat-treatment performed for same duration
M3 (10/19): Compare microstructures of A356 cast with and without ultrasonic processing

Accomplishments (Heat-treatment) Baseline Property Measurement



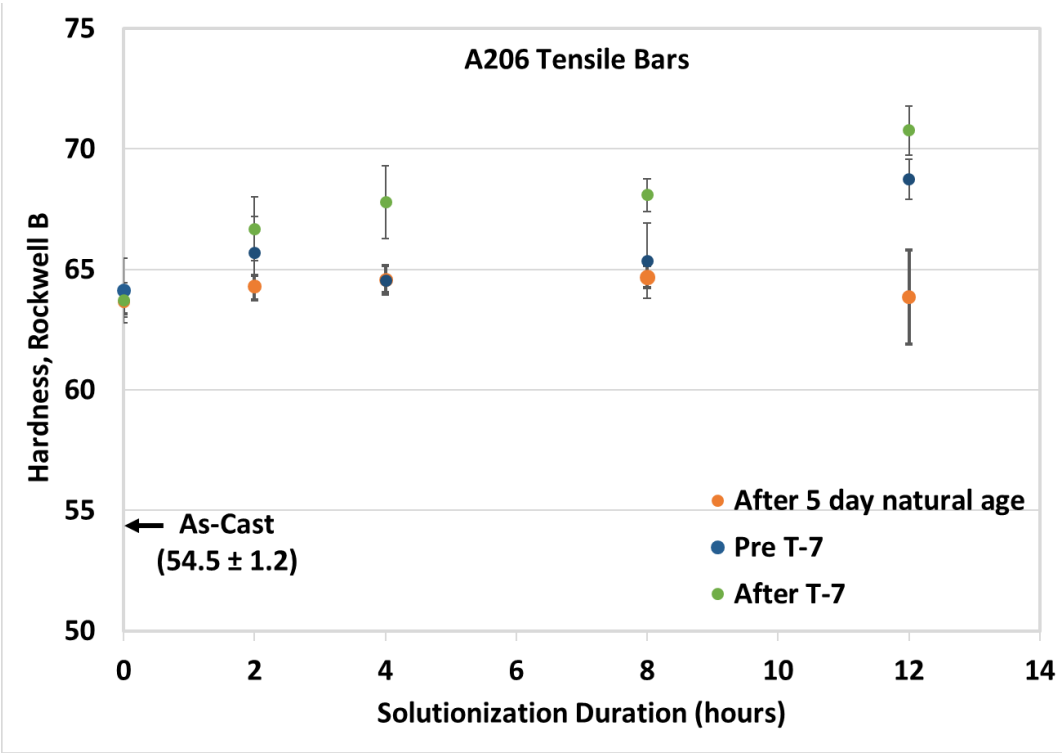
Measure hardness, after room-temperature aging, as a function of solutionization duration (0, 2, 4, 8, 12 hours)

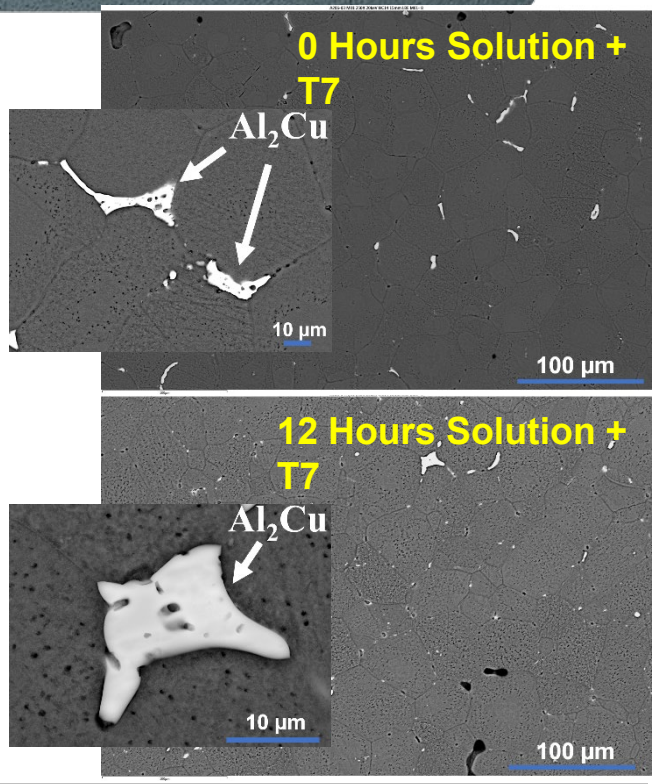


Large volume fraction of $Al_2Cu(\theta)$ precipitates along grain boundaries

Goal is to establish a baseline (e.g. of hardness) to compare the efficacy of new heat-treatments relative to current practice

Accomplishments (Heat-treatment) Baseline Property Measurement

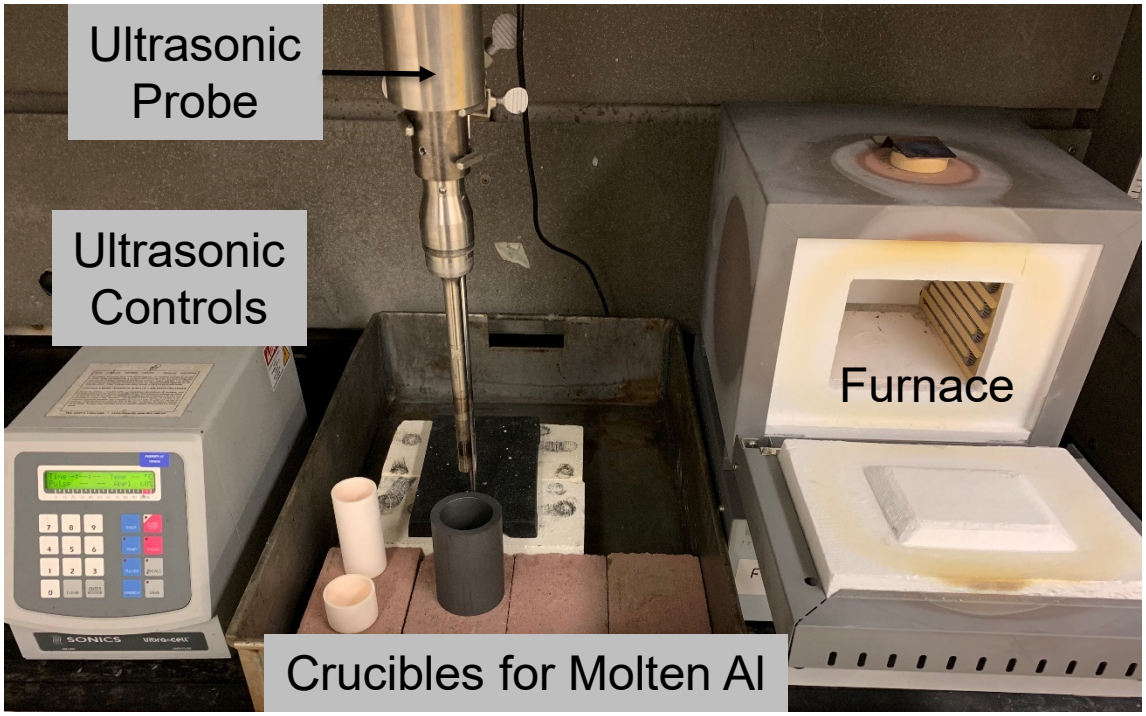




- Increasing solution duration produces some increase in T7 hardness but not so much after 5-day natural aging

- Residual Al_2Cu (θ) at the grain boundaries after 12 hours solutionization

Accomplishments (Melt Processing)
Setup for Ultrasonic Processing



- Fabricate samples with and without ultrasound and compare microstructures and mechanical properties (tensile)

- Process variables:
  - Starting melt temperature
  - Temperature for the application of u/sound
  - Ultrasonic power
  - Ultrasonic duration

Responses to Previous Years Reviewers' Comments

- This is the 1ST year of this project for AMR review, therefore there are no reviewer comments from prior years

Collaboration and Coordination

Eck Industries

- CRADA between PNNL and Eck
- Al alloys supplied by Eck
  - A206 as-cast tensile samples for heat-treatment
  - Primary A356 ingot with “low” Fe% and A356 with “high” Fe% to mimic secondary alloy
- Baseline heat-treatments
- Tensile testing of heat-treated bars

Remaining Challenges and Barriers

- Process parameters for both, heat-treatment and ultrasonic-melt processing need to be optimized
- Reaction between molten Al alloy and ultrasonic probe needs to be prevented
- Techno-economic feasibility of these techniques, though outside the scope of this work, needs to be addressed, such as:
  - Throughput (e.g. number of parts per run; lbs. molten metal per run)
  - New/existing equipment


Heat-treatment Furnaces (Eck)


Ultrasonic Processing of Al Melt (Eck)

Proposed Future Work

- Evaluation of heat-treatment parameters
  - Hardness and tensile stress-strain (ductility)
- Solidification under ultrasonic
  - Coatings/ceramic ultrasonic probe
  - Tensile stress-strain (ductility)
- Microstructural characterization
  - A206: Dissolution of Cu-containing phases during solutionization
  - A356: Morphology and size/size-distribution of Fe-containing brittle intermetallic phases in A356 with low and high-Fe content

Any proposed future work is subject to change based on funding levels

Summary

- Although opportunities exist to enable greater use of Al castings for automotive lightweighting, greater cost of primary alloy and poor properties of secondary alloys are a hinderance
- A206 Al alloy requires a solutionization heat-treatment that, if shortened, has the potential to lower the heat-treatment cost of its castings
- Greater Fe% in secondary A356 Al alloy leads to poorer ductility relative to primary A356 Al (with lower Fe%)
    - Ultrasonic processing of molten metal has the potential to refine cast microstructure and intermetallic shape/size distribution that, in turn, may improve ductility of secondary A356 Al